What is claimed is:

1. A solid oxide regenerative fuel cell, comprising:

a ceramic electrolyte;

a first electrode which is adapted to be positively biased when the fuel cell operates in a fuel cell mode and in an electrolysis mode; and

a second electrode which is adapted to be negatively biased when the fuel cell operates in the fuel cell mode and in the electrolysis mode;

wherein the second electrode comprises less than 1 mg/cm^2 of noble metal.

2. The fuel cell of claim 1, wherein the second electrode comprises less than 20 weight percent of noble metal.

3. The fuel cell of claim 2, wherein the second electrode comprises less than 0.1 mg/cm^2 of noble metal and less than 1 weight percent of noble metal.

4. The fuel cell of claim 3, wherein the second electrode comprises no noble metal or an unavoidable trace impurity amount of noble metal.

5. The fuel cell of claim 3, further comprising a first device which is adapted to provide a sufficient reducing atmosphere to the second electrode when the fuel cell operates in the electrolysis mode to prevent the second electrode from oxidizing.

6. The fuel cell of claim 5, wherein the first device comprises a hydrogen conduit operatively connected to at least one of a hydrogen compressor and a hydrogen fuel storage vessel.

7. The fuel cell of claim 6, wherein the hydrogen conduit is operatively connected to a fuel inlet of a fuel cell stack and a fuel outlet of the fuel cell stack is operatively connected to a water-hydrogen separator.

8. The fuel cell of claim 7, wherein the water-hydrogen separator is operatively connected to the fuel inlet of the fuel cell stack and is adapted to provide water to the second electrode when the fuel cell operates in the electrolysis mode.

9. The fuel cell of claim 6, further comprising a valve which is adapted to bleed a first sufficient amount of hydrogen from at least one of the hydrogen compressor and the hydrogen fuel storage vessel through the hydrogen conduit to the second electrode to prevent the second electrode from oxidizing when the fuel cell operates in the electrolysis mode and which is adapted to provide hydrogen fuel from the hydrogen storage vessel through the hydrogen conduit to the second electrode in a second amount greater than the first amount when the fuel cell operates in the fuel cell mode.

10. The fuel cell of claim 6, wherein the first device comprises a forming gas conduit operatively connected to a forming gas storage vessel.

11. The fuel cell of claim 6, wherein the first device comprises a carbon monoxide conduit operatively connected to a carbon monoxide storage vessel.

12. The fuel cell of claim 1, further comprising a first means for providing a sufficient reducing atmosphere to the second electrode when the fuel cell operates in the electrolysis mode to prevent the second electrode from oxidizing.

13. The fuel cell of claim 12, wherein the first means is a means for providing hydrogen fuel to the second electrode when the fuel cell operates in the fuel cell mode.

14. The fuel cell of claim 13, further comprising:

a second means for providing water to the second electrode when the fuel cell operates in the electrolysis mode;

a third means for removing oxygen generated at the first electrode when the fuel cell operates in the electrolysis mode;

a fourth means for providing an oxidizer to the first electrode when the fuel cell operates in the fuel cell mode; and

a fifth means for removing water from the second electrode when the fuel cell operates in the fuel cell mode.

15. The fuel cell of claim 5, wherein the second electrode comprises at least one of Ni, Cu, Fe or a combination thereof with an ionic conducting phase.

16. The fuel cell of claim 15, wherein the second electrode consists essentially of a Ni-YSZ cermet.

17. The fuel cell of claim 15, wherein:

the second electrode consists essentially of a Ni-doped ceria cermet; and

the electrolyte comprises a doped ceria portion in contact with the second electrode and a YSZ portion in contact with the first electrode.

18. The fuel cell of claim 15, wherein:

the electrolyte comprises YSZ, doped ceria or a combination thereof; and

the first electrode comprises at least one of LSM, LSCo, LCo, LSF, LSCoF, PSM or a combination thereof with an ionic conducting phase.

19. A solid oxide regenerative fuel cell, comprising:

a first electrode which is adapted to be positively biased when the fuel cell operates in a fuel cell mode and in an electrolysis mode;

a second electrode which is adapted to be negatively biased when the fuel cell operates in the fuel cell mode and in the electrolysis mode, wherein the second electrode comprises less than 1 mg/cm^2 of noble metal; and

a first means for conducting oxygen ions from the first electrode to the second electrode when the fuel cell operates in the fuel cell mode and for conducting oxygen ions from the second electrode to the first electrode when the fuel cell operates in the electrolysis mode.

20. The fuel cell of claim 19, wherein the second electrode comprises less than 20 weight percent of noble metal.

21. The fuel cell of claim 20, wherein the second electrode comprises less than 0.1 mg/cm^2 of noble metal and less than 1 weight percent of noble metal.

22. The fuel cell of claim 21, wherein the second electrode comprises no noble metal or an unavoidable trace impurity amount of noble metal.

23. The fuel cell of claim 19, further comprising a second means for providing a sufficient reducing atmosphere to the second electrode when the fuel cell operates in the electrolysis mode to prevent the second electrode from oxidizing.

24. The fuel cell of claim 23, wherein the second means is a means for providing hydrogen fuel to the second electrode when the fuel cell operates in the fuel cell mode.

25. The fuel cell of claim 24, further comprising:

a third means for providing water to the second electrode when the fuel cell operates in the electrolysis mode;

a fourth means for removing oxygen generated at the first electrode when the fuel cell operates in the electrolysis mode;

a fifth means for providing an oxidizer to the first electrode when the fuel cell operates in the fuel cell mode; and

a sixth means for removing water from the second electrode when the fuel cell operates in the fuel cell mode.

26. The fuel cell of claim 19, wherein:

the first electrode comprises at least one of LSM, LSCo, LCo, LSF, LSCoF, PSM or a combination thereof with an ionic conducting phase; and

the second electrode comprises at least one of Ni, Cu, Fe or a combination thereof with an ionic conducting phase.

27. The fuel cell of claim 26, wherein:

the first electrode consists essentially of LSM; and

the second electrode consists essentially of a Ni-YSZ cermet.

28. A solid oxide regenerative fuel cell, comprising:

a first electrode which is adapted to be positively biased when the fuel cell operates in a fuel cell mode and in an electrolysis mode;

a second electrode which is adapted to be negatively biased when the fuel cell operates in the fuel cell mode and in the electrolysis mode, wherein the second electrode comprises less than 1 mg/cm^2 of noble metal;

a first means for conducting oxygen ions from the first electrode to the second electrode when the fuel cell operates in the fuel cell mode and for conducting oxygen ions from the second electrode to the first electrode when the fuel cell operates in the electrolysis mode; and

a second means for providing a sufficient reducing atmosphere to the second electrode when the fuel cell operates in the electrolysis mode to prevent the second electrode from oxidizing.

29. The fuel cell of claim 28, wherein the second electrode comprises less than 20 weight percent of noble metal.

30. The fuel cell of claim 29, wherein the second electrode comprises less than 0.1 mg/cm^2 of noble metal and less than 1 weight percent of noble metal.

31. The fuel cell of claim 30, wherein the second electrode comprises no noble metal or an unavoidable trace impurity amount of noble metal.

32. The fuel cell of claim 28, wherein the second means is a means for providing hydrogen fuel to the second electrode when the fuel cell operates in the fuel cell mode.

33. The fuel cell of claim 32, further comprising:

a third means for providing water to the second electrode when the fuel cell operates in the electrolysis mode;

a fourth means for removing oxygen generated at the first electrode when the fuel cell operates in the electrolysis mode;

a fifth means for providing an oxidizer to the first electrode when the fuel cell operates in the fuel cell mode; and

a sixth means for removing water from the second electrode when the fuel cell operates in the fuel cell mode.

34. The fuel cell of claim 28, wherein:

the first electrode comprises at least one of LSM, LSCo, LCo, LSF, LSCoF, PSM or a combination thereof with an ionic conducting phase; and

the second electrode comprises at least one of Ni, Cu, Fe or a combination thereof with an ionic conducting phase.

35. The fuel cell of claim 34, wherein:

the first electrode consists essentially of LSM; and

the second electrode consists essentially of a Ni-YSZ cermet.

36. A method of operating a solid oxide regenerative fuel cell, comprising:

operating the solid oxide regenerative fuel cell in a fuel cell mode by providing a fuel to a negative electrode and providing an oxidizer to a positive electrode to generate electricity and water vapor at the negative electrode;

operating the solid oxide regenerative fuel cell in an electrolysis mode by providing electricity to the fuel cell and providing water vapor to the negative

electrode to generate fuel at the negative electrode and oxygen at the positive electrode; and

providing a sufficient reducing atmosphere to the negative electrode when the solid oxide regenerative fuel cell operates in the electrolysis mode to prevent the negative electrode from oxidizing, wherein the negative electrode comprises less than 1 mg/cm^2 of noble metal.

37. The method of claim 36, wherein the fuel and the reducing atmosphere comprise hydrogen.

38. The method of claim 37, wherein the water to hydrogen ratio at the negative electrode during the electrolysis mode is 8 or less.

39. The method of claim 36, wherein the reducing atmosphere comprises forming gas.

40. The method of claim 36, wherein the reducing atmosphere comprises carbon monoxide.

41. The method of claim 36, wherein the negative electrode comprises less than 20 weight percent of noble metal.

42. The method of claim 41, wherein the negative electrode comprises less than 0.1 mg/cm^2 of noble metal and less than 1 weight percent of noble metal.

43. The method of claim 42, wherein the negative electrode comprises no noble metal or an unavoidable trace impurity amount of noble metal.

44. The method of claim 43, wherein:

the positive electrode comprises at least one of LSM, LSCo, LCo, LSF, LSCoF, PSM or a combination thereof with an ionic conducting phase; and

the negative electrode comprises at least one of Ni, Cu, Fe or a combination thereof with an ionic conducting phase.

45. The method of claim 44, wherein:

the positive electrode consists essentially of LSM; and

the negative electrode consists essentially of a Ni-YSZ cermet.

46. The method of claim 36, wherein the reducing atmosphere does not chemically participate in the electrolysis process and is cycled through the fuel cell without being consumed.

47. The method of claim 46, wherein the fuel cell is cycled between the fuel cell mode and the electrolysis mode at least 30 times.

48. The method of claim 47, further comprising:

generating hydrogen at the negative electrode in the electrolysis mode by electrolysis of water vapor;

providing remaining water vapor and the generated hydrogen to a water-hydrogen separator to separate the hydrogen from water;

providing the separated hydrogen to a compressor;

providing a first portion of the compressed hydrogen to a hydrogen storage vessel; and

providing a second portion of the compressed hydrogen to the negative electrode to maintain the sufficient reducing atmosphere at the negative electrode.